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ALL WHEEL HYDRAULIC DRIVE SYSTEMTechnical Field

Ins. A1

This invention relates to a hydraulic drive system for a vehicle having all of its wheels driven by separate hydraulic drive motors. More particularly, this invention relates to such a drive system applied to specialized vehicles, such as riding greens mowers, riding fairway mowers, etc., for operating on turf, grass or the like.

Background of the Invention

Greens mowers are well known machines used for cutting grass to extremely low heights of cut. As such, they are used primarily for cutting grass on golf greens and the like. Typical greens mowers have a plurality of reel type cutting units carried on a frame with the frame being supported by ground engaging wheels. Greens mowers come in both walk behind and riding versions. The Toro Company of Minneapolis, Minnesota, is a well known manufacturer of such greens mowers.

Many riding greens mowers built by The Toro Company have a three wheel or tricycle configuration. In other words, the frame of the vehicle is supported by three ground engaging wheels comprising two front drive wheels and a single, steerable rear wheel spaced between and set rearwardly from the two front drive wheels. The frame carries an engine in the rear located generally over the rear wheel, a seat for the operator, and a steering wheel for allowing the operator to turn the rear wheel to guide the greens mower.

In addition, the greens mower frame typically carries three reel type cutting units also arranged in a tricycle

configuration. Two front cutting units are placed in advance of the front drive wheels with a third, center cutting unit being arranged rearwardly of and in the center of the frame behind the two front cutting units. The Greensmaster 3100 built and sold by The Toro Company is a typical greens mower of this type.

The Toro Company also builds other riding mowers which are quite similar to greens mowers, but are adapted to mowing other portions of a golf course, e.g. fairways, tees and the like. One such vehicle is the Reelmaster 216 which is also built and sold by Toro. Like the Greensmaster 3100, the Reelmaster 216 is a three wheel vehicle with three reel type cutting units arranged at the front of the machine.

Some differences do exist between fairway mowing units and greens mowers. For example, the Reelmaster 216 has a front mounted as opposed to a rear mounted engine. Another difference relates to the type of tires used on the wheels. A greens mower cannot risk marring or scuffing the surface of the greens and, thus, uses bald tires without any tread. However, such tires have relatively poor traction. A fairway mower, such as the Reelmaster 216, would use treaded tires.

Riding mowers of the type just described are often powered by hydraulic drive systems. Such systems include individual hydraulic drive motors applied to selected ones of the drive wheels and driven by a conventional hydraulic variable speed pump. In many greens mowers, including the Greensmaster 3100, just the front drive wheels are driven to provide a two wheel drive. However, in other cases such as in the Reelmaster 216, at least one version of this product is sold in which all three of the drive wheels can be driven to provide three wheel drive. Three or all wheel drive generally provides superior traction.

One difficulty faced by these types of products, and particularly with greens mowers, is a tendency for these

products to have at least one of the drive wheels slip, and thus lose traction, under various operational conditions. This will bring the vehicle to a halt, requiring the operator to back the vehicle up or perform some other maneuver to regain traction and regain the ability to drive. This is a major annoyance while mowing especially if it happens frequently. It cuts down on the productivity of the mower requiring that a longer time be spent mowing a particular area of grass.

The tendency for drive wheel slippage in such vehicles is brought about, in part, by their unusual geometry and weight distribution as well as by the environmental conditions they encounter while operating. These mowers, particularly mowers like the Reelmaster 216, are often used to mow quite hilly areas, e.g. the hills and swales in the fairways or around greens, bunkers, tees and the like. Often, they traverse the hill in a sideways or diagonal fashion with the uphill drive wheel carrying little of the vehicle's weight. The grass is often wet and thus relatively slick. In addition, when making a cutting swath across the hill, the cutting units will be placed down on the ground so that their weight is not being carried by the vehicle frame but by the ground.

Given the relatively small overall weight of the unit to begin with, the uphill wheel in this scenario will often slip and lose traction, bringing the unit to a halt. The operator then has to somehow maneuver the unit, by backing it up or allowing it to roll back down the hill, to regain traction. The disadvantages of this are apparent as discussed above.

As noted earlier, the Reelmaster 216 is sold in a three wheel drive version which offers better traction than the two wheel drive version. However, the hydraulic drive system for this vehicle connects all of the wheel drive motors in parallel to the source of the pressurized fluid,

2 i.e. to the hydraulic pump. This is done in part to provide  
4 a natural differential action to allow the various wheels to  
6 turn at different speeds during a turn. However, in such a  
8 drive system, when any one wheel starts to slip, the system  
10 naturally tends to supply more fluid to the slipping wheel  
12 motor, thus reducing the tractive effort from the other  
14 drive wheels. Thus, even in the known three wheel drive  
16 versions of the Reelmaster 216, when one of the front drive  
18 wheels starts to slip, generally the uphill wheel during a  
20 diagonal traverse across a hill, the unit will still come to  
22 a stop.

24 One might think that a hydraulically driven greens  
26 mower, which ostensibly mows just the surface of a golf  
28 green, would be less likely to encounter wheel slippage  
30 conditions than a product like the Reelmaster 216 which is  
32 meant to mow more hilly areas of the golf course. However,  
34 the reverse is generally true with wheel slippage often  
36 being a more acute problem in a greens mower. This is due  
primarily to the less favorable weight distribution in a  
greens mower, arising from the use of a rear mounted engine  
that is not located over the front drive wheels, to the use  
of a two wheel drive system, and to the use of bald tires  
which have no traction enhancing tread. It is also due to  
the fact that such greens mowers are not immune from having  
to traverse hilly areas.

For example, it is common when cutting a golf green  
with a riding greens mower to make a first cutting swath  
across the green, to turn around in a tight circle off the  
surface of the green, and to then come back and make a  
second cutting swath across the green which is immediately  
adjacent to the first swath but in an opposite direction.  
During the time when the operator is turning the greens  
mower around, i.e. after having finished the first cutting  
swath and preparatory to making the second swath, he or she  
is often turning in a tight circle immediately adjacent the

2 green. Many golf greens have hills or valleys in this area  
4 such that the greens mower often has to drive up or across a  
6 hill when turning around. This is when a greens mower is  
8 most likely to, and often does, lose traction on the uphill  
10 wheel and come to a stop.

12 In addition, many golf greens today are quite  
14 sculptured and may have different elevational levels or  
16 steps. Typical greens mowers may not be able to climb such  
18 steps. This may require that the stepped portion of the  
20 green be mowed with a walk behind greens mower, which is  
obviously less efficient than being able to simply mow the  
whole green with a riding greens mower. Other golf greens  
may be so steeply inclined that a conventional greens mower  
may not be able to drive up the incline of the green. Such  
greens can only be mowed in one direction, namely downhill,  
requiring that the operator drive around the outside of the  
green after each cutting swath to reposition the greens  
mower above the green before the next cutting swath. This  
is obviously a time consuming, and thus undesirable,  
process.

#### 22 Summary of this Invention

24 One aspect of this invention is to provide a hydraulic  
26 drive system for a riding turf vehicle that improves the  
28 traction of the vehicle to prevent or reduce the instances  
of vehicle stoppage due to drive wheel slippage and  
consequent loss of traction.

30 These and other aspects of this invention are provided  
32 by a hydraulically driven vehicle having all wheel drive.  
34 The vehicle comprises a frame having a power source thereon  
36 for supplying power. A plurality of ground engaging wheels  
are attached to the frame for movably supporting the frame  
for movement over the ground, the wheels comprising a first  
pair of wheels carried adjacent a first end of the frame and

at least one wheel spaced on the frame from the first pair of wheels carried adjacent a second end of the frame. A hydraulic drive system is provided for driving the ground engaging wheels of the frame. This drive system comprises a source of pressurized fluid and individual hydraulic drive motors operatively engaged to each of the ground engaging wheels of the frame. The drive system also includes means for connecting the hydraulic motors to the source of pressurized fluid in the following manner: the wheel drive motor(s) for the wheel(s) on the second end of the frame are connected in series to each other, to the fluid source, and to the wheel drive motors on the first end of the frame, and the wheel drive motors on the first end of the frame are connected to each other in parallel.

#### Brief Description of the Drawings

This invention will be described more completely in the following Detailed Description, when taken in conjunction with the following drawings, in which like referenced numerals refer to like elements throughout.

Fig. 1 is a perspective view of a typical riding vehicle to which the hydraulic drive system of this invention may be applied, such vehicle comprising a riding greens mower;

Fig. 2 is a schematic view of a first embodiment of a hydraulic drive system according to this invention as applied to a three wheel vehicle;

Fig. 3 is a schematic view of a second embodiment of a hydraulic drive system according to this invention as applied to a four wheel vehicle;

Fig. 4 is a perspective view of a portion of the first and second embodiments of the hydraulic drive system according to this invention, particularly illustrating an overrunning clutch used on certain drive wheels of the system; ~~and~~

Fig. 5 is a partial, exploded view of a portion of the first and second embodiments of the hydraulic drive system according to this invention, particularly illustrating one of the drive wheels, the wheel hub, and the overrunning clutch of Fig. 4 used on such wheel hub *and*

Detailed Description

Referring first to Fig. 1, a typical riding vehicle of the type to which this invention may be applied is shown as 2. Vehicle 2 comprises a riding greens mower, such as the Greensmaster 3100, which is built and sold by The Toro Company, the assignee of this invention. This invention, which relates to a hydraulic drive system for vehicle 2, is particularly well suited for use on vehicles, such as a greens mower, designed to operate on grass, turf or the like. However, this invention is not limited for use on a turf vehicle, but may be used on any hydraulically driven vehicle in which wheel slippage and loss of traction is a significant problem.

By way of background, vehicle 2 comprises a frame 4, a rear mounted engine 6, and three wheels for supporting frame 4 for movement over the ground - namely two front wheels 8 and a rear wheel 10 carried on frame 4 in a tricycle configuration. Frame 4 includes a seat 12 for supporting an operator, a steering wheel 14 for allowing the operator to turn and guide vehicle 2, and linkages (not shown) for connecting rear wheel 10 to steering wheel 14 such that rear wheel 10 is steered by manipulation of steering wheel 14. Vehicle 2 further includes a plurality of reel type cutting units comprising two front cutting units 16 mounted in front of the two front wheels 8. A center, rear cutting unit (not shown) is usually mounted on frame 4 between and behind front cutting units 16. As is true for most greens mowers, the tires on all of the wheels 8 and 10 of frame 4 are

2 supplied without any tread, namely they are "bald", to  
prevent marring or scuffing of the golf green during mowing.

4 Referring now to Fig. 2, a first embodiment of a  
hydraulic drive system according to this invention is  
6 diagrammatically illustrated as 20. Drive system 20  
includes a source 22 of pressurized fluid comprising a  
8 hydraulic pump 24 of any suitable design which pumps fluid  
from a reservoir 26. Pump 24 is driven, either directly or  
indirectly, from engine 6 of vehicle 2.

10 As shown in Fig. 2, pump 24 can be a pump having a  
fixed output, such as the Model 49911-23 pump manufactured  
12 by Dan-Foss, Inc. An infinitely variable, flow control  
valve 28 having a return line 29 to reservoir 26 can be used  
14 to regulate or control the pressure of the fluid downstream  
from valve 28. This flow control valve 28 can be connected  
16 in some fashion to controls on vehicle 2, e.g. to a foot  
pedal or the like, to allow the operator to control the  
18 speed of vehicle 2 by regulating the pressure of the fluid  
in hydraulic drive system 20. Rather than using a pump 24  
20 with a fixed output and separate flow control valve 28, a  
pump 24 having an infinitely variable output could be used.

22 Hydraulic drive system 20 of this invention comprises  
individual hydraulic drive motors applied to each of the  
24 three wheels of vehicle 2. Thus, referring to Fig. 2, the  
drive motor for rear wheel 10 is illustrated as 30 and the  
26 drive motor attached to each front wheel 8 is illustrated as  
32. These drive motors may be any conventional hydraulic  
28 drive motors known in the art. For example, drive motor 30  
may comprise a Ross Model ME210238EEEB motor manufactured by  
30 Parker-Hannifin, and drive motors 32 may comprise Ross Model  
MB100208AACG motors also manufactured by Parker-Hannifin.

32 In addition, hydraulic drive system 20 of this  
invention includes a unique hydraulic flow circuit,  
34 indicated generally as 40 in Fig. 2, for connecting drive  
motors 30, 32 to the pressurized fluid source 22, namely to  
36



the pump/flow control valve combination. Circuit 40 comprises fluid supply lines 42, 44 which connect rear wheel drive motor 30 in series both to fluid source 22 and to front wheel drive motors 32. In addition, front wheel drive motors 32 are then connected to each other in parallel as represented by the fluid supply lines 46. Suitable return lines 48 then extend from the outputs of front wheel drive motors 32 to reservoir 26 to return the fluid to reservoir 26.

While the hydraulic flow circuit 40 shown in Fig. 2 serially connects rear wheel drive motor 30 between fluid source 22 and the subcircuit comprising the parallel front wheel drive motors 32, this could be reversed. Alternatively, circuit 40 could be designed such that the parallel front wheel drive motors 32 are first connected to fluid source 22 with the output lines 48 therefrom merging together to then be serially connected to the input of rear wheel drive motor 30. The output line to reservoir 26 would then be the line leading from the output of rear wheel drive motor 30. Such a reversed fluid supply circuit would function equally well for the purposes of this invention as the circuit shown in Fig. 2.

The primary advantage of the circuit shown in Fig. 2 is that the entire pressurized fluid flow from fluid source 22, for whatever level of pressure has been chosen by the operator through use of flow control valve 28, will always pass through the single drive motor comprising rear wheel drive motor 30, either before or after passing through the parallel subcircuit used to supply the two front wheel drive motors 32. Thus, when traversing over the face of a hill, if the uphill wheel in the two wheel parallel subcircuit begins to slip, thus potentially drawing off some of the fluid supply for the other front drive wheel 8, this has no effect on the fluid supply to rear drive wheel 10. Rear drive wheel 10 will always receive maximum tractive effort

2 from fluid source 22 for a given pressurized fluid flow  
3 regardless of wheel slippage conditions on front drive  
4 wheels 8. For vehicle 2 to come to a stop, both the uphill  
5 front drive wheel 8 and rear drive wheel 10 must both  
6 simultaneously slip, and this is much more unlikely to  
7 happen.

8 In tests of hydraulic drive system 20 of this  
9 invention, it has been found that a riding vehicle 2  
10 equipped with drive system 20 shown herein has superior  
11 climbing and traction ability. For example, a Reelmaster  
12 216 type fairway mower would normally be expected to  
13 outclimb a Greensmaster 3100 type product, even if that  
14 Greensmaster were equipped with the all parallel three wheel  
15 drive system of the Reelmaster 216 type product, because of  
16 the bald tires on the Greensmaster and the less favorable  
17 weight distribution arising from its rear mounted engine.  
18 However, when a Greensmaster 3100 type mower was equipped  
19 with the serial/parallel drive system of this invention, it  
20 was found that such a mower would climb comparably to a  
21 Reelmaster 216, even with the Greensmaster's bald tires and  
22 rear mounted engine. Thus, a riding vehicle with the  
23 hydraulic drive system 20 of this invention exhibits much  
24 better traction ability than the same vehicle with a more  
25 conventional all parallel hydraulic drive system even when  
26 such a parallel system is employed to drive all three  
27 wheels.

28 While hydraulic drive system 20 illustrated in Fig. 2  
29 offers improved traction ability as noted above, it presents  
30 a problem during turns. Because rear drive wheel 10 is  
31 constantly and serially driven by hydraulic flow circuit 40,  
32 the speed of such wheel 10 would normally be constant and  
33 would lack the normal differential action provided by an all  
34 parallel hydraulic drive system. Thus, during turns, rear  
35 drive wheel 10 would not be able to speed up as needed  
36 during the turn, thus causing rear drive wheel 10 to skid or  
drag across the ground during such turns.

2 Accordingly, it is preferred that hydraulic drive  
3 system 20 of this invention provide some simple and durable  
4 means for allowing rear wheel 10 to overrun during turns to  
5 increase its speed. One preferred means for accomplishing  
6 this is illustrated in Figs. 4 and 5 by a mechanical  
7 overrunning clutch means 50, installed in the wheel hub 52  
8 to rear drive wheel 10, for transferring torque to wheel hub  
9 52 from the drive shaft 31 of rear wheel drive motor 30.  
10 Wheel hub 52 includes a flange 53 which may be secured by  
11 bolts 54 to rear wheel 10 in a known manner. Clutch means  
12 50 is a unidirectional clutch transferring torque only in  
13 one direction of rotation of drive shaft 31, namely in the  
14 forward direction of motion for vehicle 2. Clutch means 50  
15 does not drive vehicle 2 in a reverse direction when backing  
16 up, the drive from front wheels 8 being sufficient for that  
purpose.

18 The overrunning clutch means 50 comprises at least one  
19 roller clutch bearing 56 with a splined inner diameter 58  
20 which normally grips the motor shaft. More than one such  
21 bearing 56 can be used in a stacked side-by-side  
22 configuration depending on how much torque must be  
23 transferred through clutch means 50. In Fig. 5, three such  
24 bearings 56 are shown being used, but this number could be  
25 larger or smaller. Roller clutch bearing 56 is generally  
26 known in the wheel art and may comprise a Model HFL3530  
27 roller clutch bearing manufactured by the INA Bearing  
Company.

28 Clutch means 50 will release motor shaft 31 if rear  
29 wheel 10 starts to turn faster than motor shaft 31 to allow  
30 rear wheel 10 to speed up and overrun the shaft, as would  
31 occur during a turn of vehicle 2. When vehicle 2  
32 straightens out after its turn, rear wheel 10 will slow down  
33 and the overrunning clutch 50 will become reengaged to  
34 reestablish drive to rear wheel 10 at the appropriate speed  
35 of motor shaft 31. Similar clutches 50 are not required in  
36

the hubs to front drive wheels 8 since they have a natural differential action arising from their parallel hydraulic connection to each other.

Hydraulic drive system 20 of this invention has been shown as being applied to a three wheeled vehicle having two front drive wheels 8 and a single steerable rear wheel 10. The invention could also be applied to a three wheel vehicle, such as the Sand Pro or Infield Pro which are also manufactured and sold by The Toro Company, having a single, steerable front wheel 8 and two rear drive wheels 10. In this application, the circuit of Fig. 2 would still apply except that the serially connected wheel drive motor 30 would be the front wheel drive motor and the parallel wheel drive motors 32 would those to the two rear drive wheels. In this application, overrunning clutch 50 would be used on hub 52 to the single front drive wheel 8.

Again, this type of vehicle would have superior climbing and traction ability as compared to a vehicle without it. In order for such a vehicle to lose traction so completely as to come to a stop, one of rear drive wheels 10 would have to slip and front drive wheel 8 would also have to slip as well. One would have to get slippage on at least one drive wheel on each end of vehicle 2. Again, this is unlikely to happen.

Referring now to Fig. 3, it should be apparent that hydraulic drive system 20 of this invention can also be applied to a four wheel, as opposed to a three wheel, vehicle. Fig. 3 is a schematic diagram of such a system 20' as applied to a four wheel vehicle having two front drive wheels 8' powered by two front wheel drive motors 32' and two rear wheels 10' powered by two rear wheel drive motors 30'. The same reference numerals used in Fig. 2 to refer to components will be used in Fig. 3 to refer to the same components with a prime designation being used to refer to those components in the second embodiment, e.g. drive system 20' in Fig. 3 as opposed to drive system 20 in Fig 2.

2 The flow circuit 40' is much the same as in Fig. 2  
comprising a serial/parallel connection with the front wheel  
4 drive motors 32' remaining in a parallel subcircuit.  
However, both of the individual rear wheel drive motors 30'  
6 are now serially connected to each other and to the parallel  
subcircuit supplying front wheel drive motors 32'. See Fig.  
8 3. Thus, both rear wheel drive motors 30' get the full  
tractive effort being delivered by source 22' and both of  
10 the rear wheels 10' must spin, along with one of the front  
wheels 8', for the unit to come to a halt. In the  
12 application of Fig. 3, both rear wheel hubs would each be  
equipped with the overrunning clutch means 50 shown in Figs.  
4 and 5.

14 Various modifications of this invention will be  
apparent to those skilled in the art. For example, in the  
16 four wheel drive system 20' shown in Fig. 3, the two  
separate rear wheel drive motors 30' could be replaced by a  
18 single rear wheel drive motor 30' driving a solid rear axle  
that mounts rear wheels 10'. The overrunning clutch means  
20 50 would still be used in the wheel hub to each rear wheel  
in this configuration to allow each rear wheel to overrun  
22 the axle, but the axle itself would not have any  
differential built into it. Thus, the term solid rear axle  
24 would apply to any arrangement of axle shafts, e.g. a single  
solid, transverse axle shaft directly extending between the  
26 rear wheels or a single, solid transverse axle shaft used to  
drive stub shafts that are connected to the rear wheels,  
28 which transfer torque from the single rear wheel drive motor  
30 30' to each rear wheel without any differential being used  
in the axle. Accordingly, this invention is to be limited  
only by the appended claims.